Reply to: 'Comment on: "'t Hooft vertices, partial quenching, and rooted staggered QCD"'

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ABSTRACT

We reply to Creutz's comments on our paper "'t Hooft vertices, partial quenching, and rooted staggered QCD." We show that his criticisms are incorrect and result from a misunderstanding both of our work, and of the related work of Adams.

Creutz's fundamental criticism [1] of our work [2] is that we define (or act as if we can define) the "rooted continuum theory" (RCT) in two inequivalent ways: by rooting four copies of a chirally invariant formulation, or by taking the continuum limit of rooted staggered quarks. This is simply not true. We define the RCT *only* in the former way, for which Creutz agrees that the "correctness of rooting is a trivial mathematical identity" [1]. Creutz therefore misses the whole point of our argument, which is that the RCT serves as a counterexample to his "proof" [3] that rooted staggered quarks are invalid. The premises of the "proof" (in particular the strong coupling between tastes induced by nonperturbative effects) apply just as well to the RCT as to the actual rooted staggered theory. Yet in the RCT one can see by explicit, uncontroversial, calculation that the conclusions of his argument do not hold: there are no unphysical contributions to physical correlation functions, and there is no problem constructing single-taste observables.

As we have emphasized repeatedly [2, 4], showing that Creutz's "proof" is incorrect is not the same as showing the validity of rooted staggered quarks. References [2, 4] do the former, not the latter. The issue of the validity of rooted staggered quarks—*i.e.*, whether the known lattice artifacts (nonunitarity and nonlocality at physical scales when $a \neq 0$ [5]) persist as $a \to 0$—is separate, and there is a large body of analytic and numerical evidence [6] that these artifacts vanish or decouple in the continuum limit for any strictly positive quark mass(es). Without his "proof," therefore, Creutz has no basis for his claim: "The undesired effects [of rooted staggered fermions]... will survive the continuum limit" [1].

Recently, Adams [7] has examined the rooting issue in another simplified context, and also finds a counterexample to Creutz's "proof." It is therefore disingenuous for Creutz to claim that "rooting fails in this model also" [1] without mentioning that Adams actually comes to the opposite conclusion. We quote from the abstract of Ref. [7]: "Creutz's objections to the rooting trick apply just as much in this setting. To counter them we show that the formulation has robust would-be zero-modes in topologically nontrivial gauge backgrounds, and that these manifest themselves in a viable way in the rooted fermion determinant and also in the disconnected piece of the pseudoscalar meson propagator as required to solve the U(1) problem."

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[1] M. Creutz, arXiv:0805.1350 [hep-lat].

[2] C. Bernard, M. Golterman, Y. Shamir and S. R. Sharpe, Phys. Rev. D **77**, 114504 (2008) [arXiv:0711.0696 [hep-lat]].

[3] M. Creutz, Phys. Lett. B **649**, 230 (2007) [arXiv:hep-lat/0701018]; PoS **LAT2007**, 007 (2007) [arXiv:0708.1295 [hep-lat]].

[4] C. Bernard, M. Golterman, Y. Shamir and S. R. Sharpe, Phys. Lett. B **649**, 235 (2007) [arXiv:hep-lat/0603027].

[5] S. Prelovsek, Phys. Rev. D **73**, 014506 (2006) [arXiv:hep-lat/0510080]; C. Bernard, M. Golterman and Y. Shamir, Phys. Rev. D **73** (2006) 114511 [arXiv:hep-lat/0604017]; C. Bernard, Phys. Rev. D **73**, 114503 (2006) [arXiv:hep-lat/0603011]; C. Bernard, C. E. Detar, Z. Fu and S. Prelovsek, Phys. Rev. D **76**, 094504 (2007) [arXiv:0707.2402 [hep-lat]].

[6] See S. R. Sharpe, PoS **LAT2006**, 022 (2006) [arXiv:hep-lat/0610094] and A. S. Kronfeld, PoS **LAT2007**, 016 (2007) [arXiv:0711.0699], and references therein.

[7] D. H. Adams, Phys. Rev. D **77**, 105024 (2008) [arXiv:0802.3029 [hep-lat]].